

I don't know too much about this. Three or four years ago I got interested in the question of what causes people to get old, or what is physiological age. When infants are born there is a good chance that they will die early in life; then their death rate becomes quite low - the death rate from ~~one to ten~~ one to ten - the number per thousand that die each year; cancer is the principal cause of death in this region. It gets lower still in the teens and twenties, for Americans; then it starts going up.

I got interested in aging because of my interest in mental diseases. One child in 600 that is born is a Mongoloid. He is mentally deficient and has other various stigmata; his epicanthal folds are sort of odd that give him ~~th~~ a kind of Mongolian appearance. He usually has missing the palms of phylanges and an odd pattern of lines in/his hands, and his ears are funny; ~~and his ears~~ and he is mentally deficient. And sometimes people have said that these mongoloids age more rapidly than other people and they look like little old men. Well, nobody knew then what caused mongolism; and I thought that we ought to check up on their physiological age and see if they really do age more rapidly than other people. I talked about this with people who work with me; we began checking up to find out how you determine one's physiological age. If we think that people are older than their years or younger than their years - physiologically - what does that mean. The way to tell how old a person is to look at him, I've discovered. There is no way of taking a sample of blood and putting it in an apparatus and having it reveal a physiological age of 33.7 years, or anything like that. Nobody knows how to determine physiological age.

For children, you can take an X-ray picture of their wrists, and you can see the ends of the bones, where the bones are being deposited by

cartilage; and from the amount of material that has been deposited you can get a pretty good idea of how old the child is. After he gets to be 20 - from that time on, this method just doesn't work.

Of course, one characteristic thing about getting old is that you die more often (laughter). If it were an 'all or none' process for individuals, then this would be a good way. At age 30, say, you have a certain pretty small chance of dying. At ages 40, 45, 50, the chances are larger. The death rate per thousand people at age 35 is greater than at age 30; age 40 greater than age 35 and so on.

There was an Englishman named Gumperts, over a hundred years ago, who made a very interesting discovery. He plotted these specific death rates and found that they lie on an exponential curve - like this. This means that here you have a certain death rate - say $1/1000$; out here it is $2/1000$; here $4/1000$; $8/1000$; $16/1000$; $32/1000$; $64/1000$, and so on. And the nature of an exponential curve is such that these intervals are equal. For populations of human beings, these intervals are $8\frac{1}{2}$ years; you get twice as old every $8\frac{1}{2}$ years - twice the chance of dying every $8\frac{1}{2}$ years. That is the nature of the Gumpert's curve.

If you take different populations of human beings - those with a small life expectancy and those with a large life expectancy - and for these different populations, the Gumpert's time constant is $8\frac{1}{2}$ years - about 12 per cent of life expectancy of human beings at birth. If you take animals; for instance, a population of mice, and watch them. As they begin to get old, they die off more and more rapidly; and if you plot their curves, you find that their age specific death rate goes up - doubles itself every 12 per cent of their mean life expectancy. This makes it possible to carry out experiments with animals and then get information about man.

If you take a batch of mice and irradiate them with a certain amount

of radiation, you find that they die off more rapidly. And if you take other animals and irradiate them, they die off more rapidly. The same amount of radiation causes the same fractional shortening of their life expectancy - shifts their Gumpert's curves.

This isn't a very good way of drawing a Gumpert's curve; I will draw another Gumpert's curve here. The logarithm of $\frac{-1}{ndt}$, age specific death rate . . . Now, when you plot an exponential curve in this logarithmic way, you get a straight line like this; and every $8\frac{1}{2}$ years it increases by ~~3/10~~ $3/10$, which is the logarithm of 2; so an increase of $3/10$ means a doubling of the death rate. Here, I have put down the Gumpert's curve for Americans living in the United States now, and there ^{are} a lot of interesting things you can say about it. If we assume that this keeps on going, we can calculate that if you start out, say, with 100 million, how many would be left at age 117? It turns out about one; you would expect about one American out of 100 million to live to be 117. You remember that last year there was a veteran of the Civil War who lived to be 116 or 117, and he was the only one which indicates that you can extrapolate . . . (laughter).

If you had 300 million as the population of the world, you would get one that lived to be 125. I guess the stories about Methuselah have been exaggerated somewhat.

That is the Gumpert's curve for the United States. This corresponds to a ~~mean~~ mean life expectancy of about 70 years. This curve which applies to parts of Africa, Northern Rhodesia, for example, with a life expectancy of about 30 years, which represents a considerable extreme in the other direction. When you go to other countries - England, Norway, Sweden, Denmark, you get greater life expectancy; the Gumpert's curves are shifted over in this direction. This is the result of the better system of ~~units~~ medical practice in these countries (laughter). This curve down here represents a life expectancy of about 17 years

which is the curve for the Papacos Indians in Arizona; this is the minimum so far as I know. We can ask why this is so. Well, we can say that it is probably largely due to the poor state of medical practice among the Papacos Indians; and it is probably partly due to poor nutrition.

Well, here we have the extremes. If you plot the curve for the American Negro population, it is shifted about ~~about~~ five years relative to the American white population in the United states - probably poor medical practice involved there. It is pretty interesting.

You can do other things: you can plot the curve for women and the curve for men. The curve for women is about five years shifted to a longer life relative to the curve for men. They die off from not quite the same diseases, but nearly the same, and the incidence of these diseases at age of 75 for women is about the same as at at 70 for men.

You can plot the urban population and the rural population. People in the country live five years longer than people in the city. Probably a considerable part of this is a result of smog. Some of it may be the result of the strain of city life. But I think it is probably largely smog that is responsible.

There are some other interesting things that can be done. Gumpert's curves have been gathered by collecting the evidence for all sorts of populations. If we take the American population of cigarette smokers: the non-smokers have a Gumpert's curve like this; the cigarette smokers have a curve which down here starts out the same; pretty soon some difference, then deviating a little more. These are one-pack-a-day smokers. Then you have the two-packs-a-day. The Gumpert's curve for people who have smoked one pack a day for 20 years and then stopped is about the same as that for the half-pack-a-day smokers. It seems to be a pretty much an additive effect. This shift is 8 years and this is 16 years. So, the life expectancy is decreased by 8 years for people who smoke one pack a day

and by 16 years for people who smoke two packs a day. These people don't die of cancer of the lung - not all of them. Non-smokers who live in the country never die of cancer of the lung - practically never - the incidence is very low. Non-smokers, generally, have a very low incidence - about one in 300, including city people, die of cancer of the lung. Of the two-pack-a-day cigarette smokers, one-fourth of them die of cancer of the lung. So this is pretty important, but of the cigarette smokers in general who have an increased incidence of disease, the increase incidence of death over non-smokers is four times as great for death by heart disease as it is for death by lung cancer. So coronary heart disease, caused by ^{cigarette}/smoking kills off more people than lung cancer caused by cigarette smoking.

I have thought recently - here I am 59 years old and beginning to feel it - this is what happens, ^{when}/you see the Gumpert's curve; this reflects something that is going on in the cell, and nobody knows what it is. I've wondered if it could be that proteins get denatured, that sort of precipitate out in a sort of gum that settles down in the bottom of the cell and gets mixed up with the gears and interferes with its working. I tried to get Professor Mettleson interested in this idea. I thought it would be a good idea if he could do some work on aging along with his work on nucleic acid; nucleic acid is probably involved too. Nobody really knows what happens in the cell. One thing you find if you look in the cells of an old person is that many of the chromosomes are damaged. Of course, in cancer tissue, too, you find damaged chromosomes - damage by whatever causes damage - perhaps high energy radiation. Well, whatever it is that happens to people, they do get old; and as they get old they begin to feel sort of 'put'. They are not full of vim and vigor as they were when they were young; their life isn't so happy as it was in their youth - golden youth. As a matter of fact, you know, I don't think young people are happy. They

are really miserable; they haven't got adjusted to the world yet; they don't know whether they are doing the right things or not. A lot of secrets are kept from them by the old people who won't tell them the truth, hoping that they will keep out of mischief if they don't know ~~what~~ what the truth is. But after awhile, they get through this troublesome period; they get married and those problems get pretty well resolved, that is, if they are not sick and their back doesn't hurt like mine has been hurting lately - I don't know what's wrong with it. So there is a period when you are in excellent health and spirit; then you begin to get old, and after awhile, you die of course. You begin to ask, "Shouldn't I begin to smoke a pack of cigarettes a day so that I would cut off this last ^{eight} ~~years~~ years, or two packs a day and cut off the last 16 years - "I've lived a wonderful life and I wouldn't have that terrible period of misery." The fact is that this isn't what happens when you smoke one pack or two packs of cigarettes per day. What ~~happens~~ happens is that you begin to get old; the sludge comes down in the cells of your body. If you smoke two packs a day when you are 50 years old, you feel as bad as a non-smoker who is 66 does. So you just lose the 8 years or the 16 years out of the best years of your life instead of cutting off the unsatisfactory years at the end. So this isn't the solution, then, to smoke cigarettes.

It is interesting that ^{smoking} cigarettes really does increase the physiological age. I saw in the paper the other day that some people in the California Department of Public Health in Sacramento - Doctors Beakley, Drake, and Breslow, "The relationship of the amount of cigarette smoking to coronary heart disease mortality rates in men." They gathered the mortality rates of cigarette smokers - one-pack-a-day, two-packs-a-day, and non-smokers, and plotted just this - not the total cause of death - but just coronary heart disease, and got just the same Gumpert's curves -

8 and 16 years shift for coronary disease. And they point out that the increased incidence of coronary disease cause~~s~~four times as many deaths for smokers as the increased incidence of cancer causes. They quote some guys named Peglan and Kaiser who said, "Smoking is now the most dangerous drug addiction."

Cigarette smokers also die more rapidly from other diseases than do other people. They have undergone a general aging process. I might say evidence about cigar smoking and pipe smoking is also pretty good. And this evidence is that perhaps you cut a year off your life expectancy - not 8 or 16 years.

There is also evidence about drinking; it is that you increase your life expectancy (loud laughter) - if you drink a little. But the for drinking is the question of the amount of alcohol ingested a large quadratic term with negative sines. The curve moves out in a favorable direction, then turns around and comes back - for the larger amount of alcohol ingested.

I have been interest^{ed}~~ing~~ in various questions about aging and death, and I asked - I read in a journal - what was it? - not a very reliable one - Readers Digest (loud laughter) - that automobile accidents are the principal cause of the decrease in life expectancy of Americans. And I thought that this was a very interesting statement. After awhile, I got around to saying, "I wonder if it is true." So I made a calculation to find out. forty thousand people are killed each year in automobile accidents; this has stayed pretty constant for a number of years. There are about 180 million people in America, 40,000 over 180 million; we will multiply by 70 because the average person lives 70 years. $70 \times 40,00$ would be 7×400000 which is 2,800,000. And 2,800,000 divided by 180,000,000 is $\frac{1}{64}$. So, one person in 64 is killed in an automobile accident; this is the expectancy

when one is born, but of course, the average age at death is 22 years. Old people get killed once in a while, but it is mainly young ones who get killed in automobile accidents. So ~~xxxx~~ since they have about 70 years mean life expectancy, they lose 50 years off their life expectancy. So if 50 years is lost for each one killed (writes) this comes out 0.8 years. So the average decrease in life expectancy from automobile accidents is eight-tenths of a year. This isn't the principal cause of a decrease in life expectancy.

Cancer is very important; it is a great scourge. We know that many people die of cancer; in fact, 20 per cent of Americans die of cancer. And the distribution of cancer deaths corresponds pretty well to a Gumpert's curve. After we pass the childhood years when there is a rather high incidence of cancer - principal cause of death in children - the 20 per cent - that means that the death rate would be decreased by 20 per cent if cancer were eliminated. This would really be wonderful. Senator Newberger had an attack of cancer, was operated on; and I judge ~~that~~ that the operation was successful; he died of heart disease just a couple of months ago. But he became very much interested in cancer. He had been interested already and his personal experience made him still more interested. He said, "Let's appropriate 500 million dollars for a giant attack on the cancer problem and see if our scientists can eliminate the cancer." Suppose that this could be done, how much longer would we live? Each year the death rate would be 80 per cent of what it is now, and you take the logarithm of .8. The logarithm of .5 corresponds to $8\frac{1}{2}$ years; the logarithm of .8 would be - well, I could even figure that out: the log of .5 is $\log .3 - \log \text{ and a half of } 2$; and the log of .8 would be $1 - \text{the log of } 2$ so it is $\log .1$ - a tenth of the log of 2. And that means that a third of the $8\frac{1}{2}$ years, which means that it could solve the cancer problem

and Americans could live 2.8 years longer. They might die of something else - cardio-vascular disease - but they ~~would~~ might live 2.8 years longer.

It would be worth the \$500 million, I think, or even more if it could be done.

Cigarettes interest me. Last year, Americans smoked 5×10^{11} cigarettes. The cigarette companies have made bigger profits than they ever had before. They cost \$6,376,000,000 - about $1\frac{1}{2}\%$ of the national income; 5×10^{11} is 10 cigarettes per day per adult American - half a pack a day per adult American. So, the average American smokes half a pack of cigarettes per day, and the Gumperts curve - that means minus four years. Smoking cigarettes ~~causing~~ causes Americans to die four years earlier than they would if they didn't smoke cigarettes. It would probably take more than \$500 million to win out over the tobacco companies, but it would be a greater victory than winning out over cancer.

Here we have a situation that I think is a satisfactory one in that you have the opportunity of individual choice. There are other circumstances in which you don't have this opportunity - like the smog. You could, of course, move out into the desert, but the desert has been looking pretty bad to me. Up and around Bakersfield, the oil refineries there have been polluting the atmosphere terribly. You get as much smog sometimes as you have in the Los Angeles basin. But, anyhow, with cigarettes you have the opportunity of making the choice. Half of the American people are cigarette smokers and half are non-smokers; and the non-smokers don't have their life expectancy decreased at all - only a little bit as they inhale the smoke of the cigarette smokers; but the smokers have their life expectancy decreased by eight years. If we were to conquer both the cancer problem and the cigarette problem, then the life expectancy of the Americans would be increased by 6.8 years. Even though the deaths from cigarette smoking are largely due ^{in some part (20%)} to cancer, this is still true.

As the cigarette smokers would live 2.8 years longer, there would be an increased incidence of death from other diseases. These savings are truly additive despite an apparent overlapping in the effect.

Well, we can ask: what about other causes in decreases in life expectancy? I have checked up on a number of them. You have a category of disease called cardio-vascular renal disease. This is a very broad category of disease - a complex of a great many diseases - which causes about 60 per cent of deaths of Americans. There is death by coronary heart disease and by cerebral thrombosis, or hemorrhage, or by rupture of the hepatic artery or some other artery, or by kidney disease. All these diseases are linked together, and they are the principal cause of death allright - 60 per cent of the deaths. If they were all to be conquered, people would live 10 years longer, but it is a complex of disease and if you split it up into the different kinds, no one of them is equivalent to cigarette smoking. But cigarette smoking is something that can be eliminated whereas we just know enough to conquer these other diseases.

I checked up on some other things; I thought of high-energy radiation - cosmic rays or natural radioactivity - background radiation. Cosmic rays produce about 20 per cent and natural radioactivity - radium, potassium₄₀, Carbon₁₄ - about 80 per cent of the background radiation. Altogether, this amounts to about one tenth of a Rontgen per year - 7 rontgens. We know that high energy radiation of all kinds causes gene mutations which causes defective children to be born. Several per cent of the children born have congenital defects, many of them due to gene defects, and many of them, without doubt, caused by high energy radiation - 10 or 20 per cent, I think, of all gene mutations, other non-gene defects caused also to the developing embryo.

Very interesting results have been obtained by Doctors Stewart, Webb, and Hewett in England in their study of deaths in children by cancer.

These children are between zero and 10 or 11 years of age. These children die off at the rate of about one in a thousand, or one in 1200, of cancer. Dr. Stewart, Webb and Hewett checked up on all the families that they could find. There were a few per cent that they couldn't track down but they got most of them, and on a controlled population of children who hadn't died of cancer. They checked on a number of ~~extreme~~ circumstances - as many as seemed reasonable - in the life of these children, and they ruled all factors out except one. The one factor that was significant - the one difference between those children who had died and those that hadn't died - was whether or not the child had been subjected to radiation when the mother had an X-ray made of the pelvic region in the period of development of the infant. It turns out that exposure to 2 rontgens, (which is the amount you get in 20 years) doubles the chance that the child will die of cancer. So that changes it, ^{child} 1/in 1200 to 1 in 600. There is no doubt that the fetus can be damaged by even small amounts of radiation. There has been done a lot ~~is~~ of work on animals and on Hiroshima-Nagasaki survivors as to how much decrease in life expectancy you get. It turns out to be for human beings 10 days per rontgen. Professor Hardin Jones whose name is up there is Professor of Biophysics and Physiology in the Bonner Laboratory in Berkeley - ~~NEI~~ University of California. I have learned a great deal about these matters by reading his papers and even by hearing him talk; in fact, I was stimulated into taking an interest in this field through hearing him give a seminar in the physics department here about three years ago. He has just recently presented the evidence for this - 10 days per rontgen for human beings. Three years ago, he said that the value was between -1 day and -20 days. Now he has got it to -10 days with considerable reliability. That means that in 70 years background radiation gives you about 77 Rontgens, and that would be, then, minus 70 days. This doesn't mean that everybody dies 70 days earlier, but what it does

mean is that some people will have cancer produced by cosmic rays and natural radioactivity and will die 10, 20, or 30 years earlier; and other people will not be affected at all. Or some people might have an increased incidence of death from heart disease or hardening of the arteries, or damaging the various cells of the human body as they pass through them.

There is nothing much that we can do about this radiation; it exists everywhere, a little more in some places than others, but it is hardly worth while to move your place of residence because of this, not nearly so worth while as it would be to move from the city to the country, say, where you could add five years to life expectancy if you move there early enough - or if you stop smoking cigarettes.

We have medical X-rays. It is estimated that Americans receive about .015 Rontgen per year, on the average, from medical X-rays, and this would mean minus 105 days - decrease in life expectancy. Probably quite a number of leukemia, bone cancer and other forms of cancer are caused by medical X-rays. Now, much of the irradiation of medical X-rays is, of course, important, necessary. Much of our medical progress has resulted from the use of medical X-rays ~~from~~ for diagnosis and therapeutic purposes. I am thoroughly in favor of this. The only thing I am against is the misuse of medical X-rays. I know that there were, two years ago in Pasadena, obstretricians who required that every pregnant woman coming under their care have an X-ray picture made of the pelvic region. This causes damage. Probably one pregnant woman in 20 has ^{medical}/justification for having such an X-ray exposure. That means that 19 children out of 20 are born with an X-ray insult that will double the chance that they will die of cancer before they have passed the tenth year of their life - if they are similar to the British population, which we know they are.

I felt very strongly about this and on a couple of occasions I

talked about ^{this} /to groups of physicians. The other day I talked in Los Angeles to a group of physicians, telling him that I think it is wrong for medical X-rays to be misused. I think it is wrong for for dentists to say, "Send the children around every six months for X-ray pictures of ~~thier~~ jaw." I saw a statement just today ~~by~~ by Carl Morgan, the head of the health division of the Argonne National Laboratories saying that dental ~~X~~ X-ray pictures may give an exposure of 300 Rontgens to the jaw. The figures he gives are from 1.5 Rontgen and 300 Rontgen - 1.5 for good technique; 300 for poor technique. There are dentists who do say: send children around every six months; this is, of course, wrong. Sometimes the dentist will say, "But I have sometimes found a cavity under a filling that wouldn't have been detected if X-ray pictures hadn't been taken." It would have been much better to have waited until the cavity made itself evident later on.

The other day when I talked about this, some of the doctors got me to one side and said, "you just don't understand the situation; we have to take these X-ray pictures; we know that there isn't sound medical justification for it, but we have to take them to protect ourselves against malpractice suits." And I said, "You shock me terribly. This means that doctors place financial considerations - the chance that they will lose money in malpractice suits - above the welfare of their patients." And here I have been brought up to think that the doctors are serving humanity, that they have taken the Hippocratic oath. In fact, I have just read a statement by Dr. Lewis M. Orb, who is ~~just~~ shocked that Congress is considering the Forand Bill providing medical care through federal aid, providing medical care for old people. He said that the inability for the aged to pay does not prevent them from obtaining medical care. He said, "The prime concern of the medical profession is and always has been to serve humanity regardless of reward or financial gain." The Cadillacs just come along by themselves.

Well, there is no doubt that financial considerations are involved in misuse of medical X-rays, and these doctors verified this. In fact, they were responsible for making it clear to me by their discussion. This is moderately important. It may very well be that Americans - unless something is done about it - as Americans become more prosperous and more of them are able to have X-ray pictures of the pelvic regions, the death rate of all of our children will be doubled.

Another matter that interests me is airplane travel. I didn't complete my calculations on this but I have a piece of information of some interest. In 1959, there were 0.67 deaths per 100 million passenger miles on the American commercial planes, and in 1958, 0.34. The average of these is 0.50 per 100 million passenger miles, and so we can take that as a starting point. I don't know just how many passenger miles were flown, so I can't say just how much decrease in life expectancy for the average American there is, but I was interested. My wife and I travelled 70,000 miles in the period between June and December of last year. I thought it was interesting to figure out - post-opposterioria it was - how much decrease in life expectancy there would have been for before we started on the 70,000 miles. Well, you can calculate it out. Assuming that I have 20 years and she has 40 years additional life expectancy - that is an average of 30 years - it turns out, using this 0.5×10^{-8} , that it is four days. But, of course, we came through, so that it is zero now that we have come through. That was the calculation of probability before we started on the 70,000 miles of going through Africa, Japan, Australia and so on. . . .

We might ask that if you are going to go on an airplane, how much do you lose in life expenctancy per hour of traveling - in a jet at 500 miles per hour. Well, this turns out to be pretty simple. One hour of 500 miles

an hour turns out to be minus one hour in life expectancy. (Laughter)
It differs from cigarette smoking. It is easy enough to figure out - you see, you take one pack a day for 40 years, 8 years decrease in life expectancy and you multiply this out and it works out easily enough. You have 14.8 minutes decrease in life expectancy for smoking one cigarette. I haven't really carried out a thorough study on this, but I estimate that it ~~take~~ takes about 4.9 minutes to smoke a cigarette. So, it is three times as dangerous to smoke a cigarette on a time basis as to fly in an airplane. If you fly in an airplane and don't smoke cigarettes, you are three times as safe as you would be in staying at home and smoking them, and you are four times as safe as you would be flying in an airplane and smoke cigarettes.

This, I think, is a very interesting figure, that for all young people - whatever time they put in smoking cigarettes, they are losing three times that much time from their life. This is well worth knowing. I think the tobacco companies know it but you wouldn't believe it by reading the statements made by the scientists who work for the tobacco companies.

I am going to mention fallout as a cause of decrease in life expectancy, and the statement that I shall make now represents a larger effect of fallout than is represented in statements that I have made before regarding the effect of fallout in causing death by lung cancer, leukemia and bone cancer.

There is good evidence that exposure to irradiation causes physiological aging and increases in incidence of death by all causes - high energy radiation - so fallout radioactivity probably does this too. There is good evidence that 10 to 20 per cent of gene mutations are caused by natural background radiation that strike the genes or chromosomes and damage them; or damage some other molecules which then attack the genes or chromosomes. Geneticists generally say 10 per cent but I think there is pretty good evidence now that this figure is low and that it should be, say, 20 per cent.

There is good evidence that diseases such as leukemia and bone cancer and cancer of the thyroid have an incidence as the result of radiation of about 10 per cent of cases caused by background radiation. And it is likely - from this minus 10 days per Rontgen - it is likely that all diseases increase in incidence about 10 per cent from background radiation. So we can calculate from fallout what the effect would be.

Fallout is estimated to be about 5 per cent of background radiation; that would be three and one half days - not very dangerous, you see. It isn't like cigarette smoking in that you can't take it or leave it - you have to take it.

I remember the cartoon by the great cartoonist in Washington - Herb Luck - in which he said that had volunteered for all of us as guinea pigs. I don't like even this three and a half days. ~~Well~~, That is a hundredth of a year. That would mean that if it were of such a nature that it caused a catastrophic effect on a certain number of people, it might be that one person in a hundred would have one year cut off his life expectancy; or more likely, one in a thousand will have 10 years cut off his life expectancy because of fallout radioactivity and cause him to come down with cancer. So for certain individuals the effect of fallout might be a serious one, and for others, not.

Now, I haven't come yet to what may be the principal decrease in life expectancy for Americans. I just received today a very interesting volume put out by the United States Government Printing Office: Hearings ~~made~~ before the Special Sub-Committee on Radiation of the Adjunct Committee on Atomic Energy of the Congress of the United States, on biological and environmental effects of nuclear war, June 22 to 26, 1959. A lot of stuff in this book was not reported in the press when these things were carried out. There is some testimony by Professor Hardin Jones, for

example. I think it was suggested that the people who presented testimony here discussed the problem of nuclear war on the somewhat standardized basis. It was suggested that they discuss an attack on the United States involving a total of 4,000 megatons, of which half is fission and half fusion. This would be equivalent to 200 20-megaton bombs. That is about as big as they are made because there is not much use to make them bigger. One of them is enough for any city. They have been exploded - tested. On the first of March, 1954, we exploded the first 20-megaton bomb. It was called the b . . . bomb, at Bikini. It was pretty powerful; it had the energy for explosion of 20 megatons. A megaton is a million tons of TNT - equivalent. During the second world war, there were used altogether about three million tons of high explosives throughout the whole of the war. So that bomb was seven times as powerful as the whole of the second world war. And it is assumed that there ~~is~~ be an attack with 200 20-megaton bombs. This is what is described as a small nuclear attack on the United States.

In the studies made by the scientists in the Rand Corporation and other such people, large nuclear attacks have also been postulated and discussed. I have estimated that we have 100,000 nuclear bombs and that Russia has 50,000, and nobody has criticised this estimate. I think it is probably about right. Some of them are little ones like the Hiroshima-Nagasaki bombs and some of them are big ones. You can discuss a small nuclear attack in this way: The area of the United States is about 3,000,000 square miles, and I will divide it up into regions of about 100 miles square, and leave out a third of it in the mountains, say. It has become customary to talk about regions of regions 10,000 miles square; for example, this could be Los Angeles. Here would be the central part - Los Angeles, 15 miles diameter - Pasadena over here; Glendale over here. ^{When} ~~if~~ one of these bombs explodes, it smashes the city flat over an

area about 20 miles in diameter, and there the blast fire and immediate radiation effects are such that everybody is killed. Actually the destruction would be over an area somewhat larger because frame houses are set fire to 15 or 20 miles away. But it is also customary to take an area of 400 square miles in which you get complete destruction. These 200 bombs - if they exploded over the 200 biggest cities in the United States - would wipe out half the population. And then you get the effect of the radioactive fallout. The radioactive would be spread around - not uniformly - there would be more of it close up. If the wind were blowing, it would spread out in that direction; but it is customary to assume that it would pollute about 10,000 square miles. If it were uniformly distributed over the 10,000 square miles, the people in the first few hours would receive 20 times the amount of radiation necessary to cause them to die in a few days of acute radiation sickness. Some people around the periphery might well survive - might survive if they got under ground and stayed there several weeks. This is why some people say that perhaps 95 per cent of American people might be killed in such an attack - the Russian people too - because here you have about four per cent of the area that is just devastated, and the remainder - the people would be killed - almost all of them, but not for some time. There would be time for them to get their rockets or even to get into their planes and go over and drop their bombs so that complete destruction could be brought on the enemy too. What would possibly happen, of course, - if there were to be a nuclear war - is that almost everybody in the United States would be killed and almost everybody in Russia and almost everybody in England and elsewhere in Europe where there are H-bomb bases now and rockets with nuclear war heads. There would be damage done to the people ~~in~~ in the southern hemisphere, but I think that life would survive in Australia and New Zealand and South

Africa; I hate to think of the South Africans being the ones who would come through.

Here I have this report, and in agreement with what other people have said, Professor Jones has said that you could expect 5 to 20 per cent of Americans to survive a small nuclear attack. Much bigger ones have been discussed by the Rand Corporation people; and 5 to 20 per cent would survive. They would be people, in general, who have received quite a lot of radiation, probably nearly as much as they could stand without dying. He estimates that they would receive 300 Rontgens in the first week and then another 100 Rontgens during the succeeding months during the first year. If we multiply that by minus 10 days, we get 4,011 years minus 11 years in life expectancy by the aging effect of this. He also points out that in the whole of the Northeastern United States they would receive ~~xx~~ an estimated 3,500 Rontgens from the Strontium 90 in their bones, and this would cause probably 50 per cent of them to develop bone cancer. And I haven't taken that into consideration. There would be so many bombs there that I don't think there would be many survivors.

Now, if there would be a nuclear war, we can figure out what the decrease in life expectancy would be. I will assume that 90 per cent of the people would be killed, and since there is no selection on the basis of age, these would be people varying in age between zero and 70 or 80 years old. So I multiply that by 35 and this gives the decrease in life expectancy for those who are killed. And those who survive will have a decrease in life expectancy of 11 years. (I am not sure I am doing this right). Do I multiply by 10 per cent? Yes. (writes on board). This gives about 33 years decrease in life expectancy for the average American. (Q. from audience). No, only the infants would have 70 years cut off their life; old ~~mean~~ would have only their remaining year or two. The average

age of the people that are killed would be 35 years, say; and so they would have 35 years decrease in life expectancy, the rest of them 33. Of course, this is the decrease in life expectancy for Americans if there to be a nuclear war. If everybody were killed, it would be 35 years decrease in life expectancy.

We might be more interested in the question: What is the decrease in life expectancy for Americans living now because of the existence of nuclear stock piles in the world? And this requires that we make an estimate of the probability of nuclear war. When there is peace in the world, which is of course a sensible thing, then we don't have a decrease in the years that we will live. If there is a war, there is a decrease of 33 per cent. There are two possibilities - one that there be a nuclear war and one that there be no nuclear war. The simplest thing to do is to say that in the absence of information bearing closely on this question, that these have equal probability. (Writes.) So we multiply -33 by $\frac{1}{2}$ and we get $-16\frac{1}{2}$ years as the decrease in life expectancy for Americans from only the existence in the world of nuclear weapons. That makes that, then, the principal cause of the decrease in life expectancy.

Well, I know a few other things about aging and death, but I have finished the whole hour. Would you like to ask a question or two?

Ques: Have you in the past, or do you now smoke?

Dr. P: When I was about your age or younger, I thought that it was proper, something wrong if I didn't smoke cigarettes; so I smoked a few cigarettes. But fortunately I was so poor that I didn't have money enough to buy them, so I got through the danger period as a result of poverty. It was a fortunate thing; I might well have developed this drug addiction, as the fellows call it.

Ques: Reading: "Mice live up to 45 per cent longer after they have been subjected to magnetic fields. In cancerous mice after similar

treatment, " What does that mean?

Dr. P. I would say that it means that some newspaper reports are not very reliable. Maybe even some scientists aren't very reliable. I just don't believe this; it seems highly unlikely to me.

Ques: What is the effect of coffee drinking?

Dr. P. I haven't seen any statistics on the effects of coffee drinking. I saw a paper on production of gene mutations in micro-organisms by caffeine. But I thought that it is unlikely that the gonads of human beings get any appreciable amount of caffeine from coffee drinking. Some of the somatic cells may, and you may get some somatic mutation that would cause cancer, so I wondered if caffeine might not be a carcinogenic agent, but it hasn't been shown to be one so far as I am aware.

Ques: If the people who smoke cigarettes would desist from the practice, would they, because of their personality, be more apt to have heart disease?

Dr. P. Well, there has been quite a lot of study made of this. At Berkeley, during the twenties, there was quite a large population of high school students who were classified on the basis of 100 characters and they have been investigated . . . - the cigarette smokers and the non-smokers.

The smokers, even though it is rather a small population, are dying off at a greater rate than the non-smokers. This effect shows up with populations as small as 50. With 50 smokers and 50 non-smokers you get very significant results. An effort has been made to find some correlation between some one or another of these 100 characters on which they were graded when they were in high school and their smoking cigarettes and not smoking cigarettes. And there is no significant correlation with any one of the 100 characters.